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Description:

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MICROPUMP AND METHOD FOR THE PRODUCTION THEREOF

The invention relates to a micropump comprising a pump membrane which can be moved by modifying the volume of the pump chamber which is adjacent to the pump membrane and a base part, also comprising two valves which are arranged in recesses in the base part and react to the pressure in the pump chamber in order to alternately open and close an inlet channel and an outlet channel for a medium to be pumped.

The invention further relates to a method for producing such a micropump.

The lateral measurements of such micropumps which are fully or predominantly made of plastics are preferably between 5 and 30 mm for a height of 0.5 to 5 mm. The pump rates for fluids range between  $10^{-5}$  and 0.2 l/min. The main fields of application include chemical and biochemical analytics, microreaction technology, the conveyance of gases, the conveyance and dosage of pharmaceutical agents, specimen fluids, adhesives, fuels or lubricants.

Plastic micropumps have the advantage over pumps made of silicon or metals that apart from the utilization of inexpensive base materials, efficient production methods such as injection molding can be deployed. Depending on the requirements for example in connection with optical transparency, stability, hydrophilicity, hydrophobicity or chemical resistance, different plastics may be deployed using the same construction, such as for example polycarbonate, polypropylene, polyethylene, cyclo-olefin-

copolymer, polyetheretherketone, polyphenylensulfide or fluorine plastics.

DE 44 02 119 describes a micropump made of plastic comprising a membrane arranged between two shell halves which serves as a pump membrane as well as for forming movable valve bodies, and which is open-worked at valve seats.

A micropump of the afore-mentioned type is known from DE 197 20 482. By forming a pump chamber, a pump membrane is mounted on the top side of a two-part base part having recesses for valves in its interior, which can be deformed by means of a piezo actuator. A valve membrane arranged between both parts of the base part has a gap on both valve seats and thus comprises a component common to both valves.

By using relatively large valve membranes which are involved in forming both valves, the production of such micropumps is very costly. It is particularly problematic to arrange the gaps in the membrane on the valve seats with the accuracy necessary for the functioning of the valves. On the one hand, the distortion and shrinkage effects typical for plastic materials lead to big position fluctuations of the gaps on the membrane. On the other hand, misplacements of the gaps on the valve seats can occur rather easily during the assembly of the thin and cumbersome membrane film. The production yield under the conditions of serial production is thus very low.

The present invention has the object to create a new micropump of the afore-mentioned type which can be manufactured at lower costs compared to such known micropumps.

The micropump meeting this object according to the invention is characterized in that the valves are made without common components by means of stand-alone functioning valve modules featuring a valve seat and valve body.

The assembly of stand-alone functioning valve modules does not require an outlay comparable with the assembly of the valve membrane in the micro membrane pumps according to the state of the art, whose exact arrangement in the pump housing determines the operability of the valves.

Both valve modules, i.e., the inlet valve module and the outlet valve module, can be advantageously identical in construction, wherein the valve seat always points in the direction of the conveyance flow. This measure which raises the share of parts with identical construction also contributes to a reduction in production costs of the micropump.

In the preferred embodiment of the invention the recesses are designed as hollows which are open toward the pump chamber, into which the valve modules can be inserted precisely and with little effort during the final assembly of the pump.

It is practical if the height of the valve module matches the depth of the hollow. This largely prevents the formation of dead volume.

In the preferred embodiment of the invention the valve module comprises two parts with one, preferably rotationally symmetrical seat component, and a valve body arranged in a cavity in the seat component, preferably a spring component, for closing and opening a valve opening in the seat component. The opening is preferably

arranged coaxially relative to the rotational axis of symmetry for the rotationally symmetrical design of the seat component.

The spring component can be connected with the seat component in one outer ring area which is centered by the seat component, and may exhibit a lip element extending from the outer ring area inwards for closing or opening the valve opening. Differently designed spring components can be combined with the same seat component depending on the performance requirements of the micropump. Pumps with different properties differ only in regards to the spring components.

In a further advantageous embodiment of the invention, the micropump is further made of a prefabricated base module comprising a base part and hose connections, and a prefabricated actuator module which contains the membrane and if applicable, a piezo disk connected with the membrane.

Such a modular design further contributes to the reduction of production costs. Separate product development, production and quality assurance for components of the pump increase the production confidence as well as the flexibility and retooling work during the serial production of various pump variations. The stand-alone functioning modules make large positioning tolerances possible and facilitate assembly.

It is practical to design the base module, apart from the recesses in the base part, and the actuator module rotationally symmetrical, wherein the pump membrane is connected with the base part, if necessary, via a support ring which rests on a ring seat, particularly a ring shoulder, on the base part. The rotationally symmetrical parts or the tools required for their production can be produced at relatively little cost. The

actuator module can be centered with little effort on the base module without position control by means of the support ring resting on the ring seat.

The base part is preferably a disk part, wherein the channels for the inlet and outlet of the pumped medium conveniently extend perpendicularly to the disk plane, via the shortest path through the base part. This is advantageous in order to minimize the flow resistance within the micropump.

The base module can be made in one piece with the hose connections, for example, as an injection mold.

At least the pump parts which come into contact with the medium are made of plastic which is resistant against the pumped medium and, if necessary, protects parts which are not of plastic from aggressive mediums. For example, the membrane can be made of several layers in order to attain the desired deforming properties, wherein for example, a layer shielded by a plastic layer can be made of a metal.

The invention shall now be illustrated in more detail based on the embodiments and the attached drawings corresponding thereto as follows:

Fig. 1 is a sectional view of a micropump according to the invention,

Fig. 2 is a top view of the micropump of Fig. 1,

Fig. 3 shows additional embodiments for actuator modules which can be used in a micropump according to the invention,

Fig. 4 is a further illustration of an embodiment for a base module to be used in a micro membrane pump according to the invention,

Fig. 5 is sectional, side view of a valve module used in the micro membrane pump of Figs. 1 and 2,  
Figs. 6 and 7 are additional illustrations of embodiments for valve modules which can be used in a micro membrane pump according to the invention, and  
Fig. 8 shows further illustrations of embodiments for valve spring components which can be used in a micro membrane pump according to the present invention.

In Fig. 1 the reference numeral 1 designates a disk-shaped base part with a ring shoulder 17 at the circumference. The inlet connection 2 and the outlet connection 3 are attached to the base part 1. A membrane 5 connected with the ring support 4 at its outer edge by means of gluing or welding rests on the base part 1 over a ring support 4, the membrane itself being glued to a piezo disk 6. The ring support 4 could also be connected in one piece with the membrane 5.

A pump chamber 7 is formed between the membrane 5 and the base part 1 which is connected with the membrane by means of gluing or welding.

An inlet channel 8 is attached to the inlet connection 2 and an outlet channel 9 is attached to an outlet connection 3, wherein both channels each flow into a round cylindrical recess 10 or 11 in the base part 1. The channels 8 and 9 are arranged concentrically relative to the respective recess 10 and 11. Identically built valve modules 40 and 41 with a seat component 12 and a spring component 13 are seated in the recesses 10 and 11 which are formed as hollows open toward the pump chamber 7, wherein the spring component faces the inlet valve module 40 in the recess 10 of the pump chamber 7, and the spring component faces away from the outlet valve module 41 in recess 11 of the

pump chamber 7. The seat component 12 has an opening 14 facing toward the inlet channel 8.

Aside from the connections, channels and valve modules, the micropump shown in Figs. 1 and 2 is designed rotationally symmetrical to an axis 15. As can be seen in Fig. 2, the connections, channels and valve modules are arranged symmetrically relative to a plane 16 which contains the rotational symmetry axis 15 and which cuts the pump in two halves.

During the production of the micro membrane pump as shown in Figs. 1 and 2, three different modules are prefabricated independently of each other prior to their final assembly, namely the actuator modules comprising the piezo disk 6, the membrane 5 and the support ring 4, the base modules comprising the one-piece base part 1 and the connections 2 and 3, and the valve modules comprising the seat component 12 and the spring component 13.

The individual parts of the mentioned modules, as well as the modules themselves, are preferably welded together, wherein glued connections are just as suitable as welded connections.

In the respective embodiment, all parts of the pump with the exception of the ceramic piezo disk are made of plastic.

The pump made up of the modules can be easily manufactured. Since the valve modules are prefabricated as stand-alone functioning parts, the functioning of the valves does not depend on the accuracy of their arrangement.

The piezo disk 6 moves the membrane 5 for letting in the fluid to be pumped, thereby increasing the volume of the pump chamber 7.

At the beginning of the inlet phase the membrane is dented as shown in the respective illustration of the embodiment. The created negative pressure lifts the spring component 13 of the inlet valve module 40 off its opening 14. The medium to be pumped flows via the inlet channel 8 through the released opening 14 and cutouts in the spring component (Fig. 5) into the pump chamber 7. At the end of the inlet phase according to this embodiment, the membrane 5 has its flat form as shown in Fig. 1. The spring component 13 of the inlet valve module 40 closes during the renewed denting of the membrane 5 by means of the piezo disk 6 and the creation of a positive pressure in the pump chamber 7. Meanwhile, the spring component 13 of the outlet valve module 41 lifts off its opening 14. In the lifted position the spring component 13 of the outlet valve module 41 remains retracted relative to the floor of the recess 11. A medium to be pumped can now drain off through the opening 14 of the outlet valve module 41, a clearance 42 formed between the spring component 13 and the floor of the recess 11, and the outlet channel 9. The actuator moves periodically with frequencies typically between  $10^0$  and a few  $10^2$  Hz.

In the following figures identical parts or parts with identical functions are designated with the same reference number as in previous figures, wherein a letter a, b, etc. is consecutively added to the respective reference numbers from figure to figure.

Fig. 3a shows an actuator module with a support ring 4a, a membrane 5a and a piezo disk 6a, wherein the membrane 5a comprises two layers 18 and 19. The layer 18 is made of a metal, for example, steel or brass. The layer 19 adjacent the pump chamber and therefore adjacent the medium is made of a plastic. The desired deforming performance of the membrane is attained by means of the metal layer. The plastic layer protects the metal

layer from aggressive transport material and is resistant against the medium to be pumped. Semi-crystalline plastics, such as polypropylene, amorphous plastics, such as polycarbonate, or high-performance plastics, such as polyphenylene sulphide, polyetheretherketone or plastic containing fluorine may be deployed for this purpose.

An actuator module shown in Fig. 3a exhibits a membrane 5b comprising two such layers 18b and 19b and a piezo disk 6b. The module is attached without a support ring directly onto a base part, which differs from the base part of Fig. 1 in that no ring shoulder 17 is provided. Rather, a rim heightening could form a centering seat. Consequently, a self-priming pump suited for pumping small volume flows results with a pump chamber volume that fluctuates between 0 and a maximum value, wherein the membrane 5b is only deformed by means of the piezo disk 6b.

An additional actuator module for such a pump is shown in Fig. 3c whose pump chamber volume fluctuates between 0 and a maximum value. A membrane 5c connected with a piezo disk 6c exhibits on its side facing the pump chamber a recess corresponding to the maximum pump chamber volume, which disappears during the denting of membrane 5c by means of the piezo disk 6c.

Fig. 3d shows an actuator module with a cap-like shaped membrane 5d made of plastic, which is connectable via a flange 36 with the base module. The resetable membrane 5d may be dented for example directly by hand with the thumb or by means of an appropriate tappet of an actuator which is temporarily or permanently connected with the pump. Compared to an actuator module with a piezo disk, longer membrane lifts and correspondingly bigger changes in the pump chamber volume can be achieved. A micropump

with such a membrane could be deployed for example in the context of environment protection for taking samples.

Fig. 4 shows an alternative embodiment of a base module with a base part 1c, which is formed in one piece with an inlet connection 2c and an outlet connection 3c.

Figs. 5 and 6 show in more detail the design of the valve modules 40 and 41 used in the micro membrane pump of Figs. 1 and 2.

The seat component 12 of the valve module exhibits a floor plate 20 and a ring-shaped rim heightening 21 by means which a vessel-like cavity is created for the spring component 13. The height of the rim heightening is equal to the depth of the recesses 10 and 11. The top side of the spring component is positioned backwards against the rim heightening 21. The spring component 13 is glued or welded via a ring-shaped rim area 22 to the seat component 12. As can be seen in Fig. 6, the spring component 13 exhibits a lip element 23 which spans the ring-shaped rim area diametrically with an expansion 24 in the area of a valve seat 29. The spring component 13 can be made out of a plastic film, wherein the film thickness can be between 0.01 and 0.3 mm.

Under the influence of pressure in the pump chamber 7 the lip element 23 lifts, particularly its expansion 24, while releasing the opening 14 off the seat area or lies against the seat area while closing the opening. When the valve is open, the medium which is discharged from the opening 14 can flow through the openings formed by the cutouts 25 and 26 in the spring component 13 and reaches the pump chamber 7 or the outlet channel 9.

In the embodiment for a valve module according to Fig. 7a, a ring heightening 27 extending from a floor plate 20a is formed in the

area of the valve seat, which provides for a suitable prestressing of the elastic lip element 23a and thus enables a secure closing of the valve.

In the embodiment of Fig. 7b an elevated rim seat 28 is formed next to a rim heightening 27b on the valve seat, which lifts a lip element 23b over its entire length from a floor plate 20b. This embodiment has the advantage that the particles transported along with the conveyed material cannot settle between the bottom side of the lip element and the floor plate.

In the following further embodiments for circular spring components are described which can be optionally installed in the seat component 12.

In the embodiment shown in Fig. 8a a lip element 23c with an expansion 24c in the seat area is connected only at one end with the remaining spring component, and a slot cutout 30 is formed. By means of such a design, low spring constants of the lip element can be attained.

In the embodiment shown in Fig. 8b a lip element 23d with an expansion 24d in the area of the valve seat is formed through slot cutouts 31 and 32, which is connected at both ends with the remaining spring component. The spring constant of this lip element which connected with both sides to the remaining spring component can be higher than that of the preceding embodiment. The expansion 24d is less inclined to tilting and thus rests more evenly on the valve seat than in the previous embodiment.

An even higher spring constant and resting evenness is achieved by the embodiment of Fig. 8c, wherein a three-armed lip element 23e with an expansion 24e is formed through three slot cutouts

33, 34 and 35. The junctures of the lip element with the remaining film are evenly dispersed across the circumference of ring area which is provided for the connection with the seat component.

In the embodiment of Fig. 8d two slot cutouts 31f and 32f which are nested in one another are provided through which an almost ring-shaped lip element with an inwardly protruding expansion 24f is formed. In this embodiment, a comparatively low spring constant of the lip element 23f can be combined with an even arrangement of the expansion 24f in the valve seat area.

Fig. 8e shows a spring component with a straight lip element 23g formed through two slot cutouts 31g and 32g, having an expansion 24g which protrudes laterally toward the middle of the spring component.

All of the spring components shown in Fig. 8 feature narrow openings which follow the contours of the lip element and which advantageously do not form a large dead volume. Depending on the design, the spring constants of the lip element are between 0.8 mN and 0.0005 mN per micrometer deflection.